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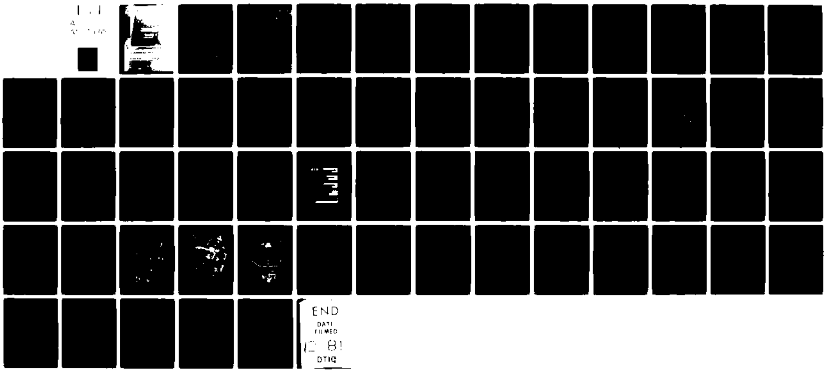

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This research study investigated whether reading effectiveness of procedural texts for a performance task is influenced by media formats which differed in design according to the Educational Cognitive Style (ECS) preference of the user/reader. Significant individual differences among the cognitive style types in their ability to follow the directions was found. One cognitive style type in particular tended to be more compatible with processing and understanding the technical information.

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Statistically significant differences were also found to result from the effect of media format design--graphics had a strong facilitative effect on user efficiency and accuracy.

These results indicated that to plan and design effective instructional materials which maximize the users' understanding of the task, designers should recognize and focus on the users' strengths and weaknesses for processing technical information. A model for designing technical instructions based on the users' needs was presented.

ABSTRACT

This research study investigated whether reading effectiveness of procedural texts for a performance task is influenced by media formats which differed in design according to the Educational Cognitive Style (ECS) preference of the user/reader. Significant individual differences among the cognitive style types in their ability to follow the directions was found. One cognitive style type in particular tended to be more compatible with processing and understanding the technical information. Statistically significant differences were also found to result from the effect of media format design--graphics had a strong facilitative effect on user efficiency and accuracy.

These results indicated that to plan and design effective instructional materials which maximize the users' understanding of the task, designers should recognize and focus on the users' strengths and weaknesses for processing technical information. A model for designing technical instructions based on the users' needs was presented.

TECHNICAL COMMUNICATION -- TAKING THE USER INTO ACCOUNT

People in all sectors of the economy today share an increasing dependence on sophisticated equipment and detailed procedures to assist them in performance of their work. Meanwhile, the efficient use of such equipment and the accurate adherence to such procedures has come to depend, to a large degree, on the information that the user obtains from a variety of instructional materials, including technical manuals, films, and tapes. Frequently, these instructional materials are intended to guide the user in carrying out a set of procedural directions with maximum efficiency and minimal error under limited supervision and often in stressful environments. It is important, therefore, that such technical materials be designed to maximize their communication value and to overcome, as much as possible, any motivational resistance to their use.

The importance of technical materials that are clear and easy to understand is intuitively obvious. But what constitutes a clear procedural set of directions depends upon the ability of the technical communicator to present the instructions to the user in a format which conveys the information efficiently and accurately. In turn, comprehension on the part of the users is measurable to the extent that they can use the directions to complete a task quickly and with a minimum of error.

The problem of how to present procedural information is apparently endemic to most people working in the field of technical writing. The instructions may dictate the use of technical terms which are unfamiliar to the typical reader. The content often deals with contingencies (if this . . . then that) or sequencing (do this . . . then that). How should writers order the text for a procedural task? Should they apply the standard readability indices proposed by Chall (1958) or Klare (1972)? Do they ask the technical artist if an illustration or graph should accompany a particular text? Questions like these have been asked by researchers interested in producing some practical guidelines for designing procedural materials (see Frase, 1973; Farr and Waller, 1976; MacDonald-Ross and Waller, 1975: Mager, 1961: and Rothkoph, 1976). In spite of the extensive literature available, the researchers found that there are very few scientifically based facts on which technical communicators can rely to design and produce technical materials.

Research by Farr and Waller (1976), Frase (1973), Hartley (1980), MacDonald-Ross and Waller (1975), and Rothkoph (1976) indicates that there are few guidelines available to serve as a basis of understanding how readers comprehend technical materials. Given the critical importance of understanding printed instructional materials for industrial and military training and equipment operation, it is surprising that more attention has not been given by reading researchers to the design contingencies facing technical writers.

Need for Improved Technical Manuals for DOD

The fact that printed materials are not always effective is carefully documented in a recent General Accounting Office report (Improving Management of Maintenance Manuals Needed in DOD, 1979). Spiraling innovations in technology have beset the military services with perhaps an even greater dependence upon printed instructional materials for disseminating technical information than other sectors of society. The Department of Defense (DOD), for example, spends over $20 billion annually to maintain systems and equipment valued at hundreds of billions of dollars. It also spends hundreds of millions of dollars to procure, distribute, and update procedural manuals. An effective national defense and the safety of personnel, coupled with the multi-billion dollar investment in military hardware and hardware maintenance, make it apparent that military manuals must be accurate, timely, and readily understood (GAO Report, 7/1979).

The GAO in its recent review, however, found that military service manuals often are not easy to use and frequently are not current or accurate; consequently, job efficiency by maintenance staff has been hindered. Studies by both DOD and private contractors found military manuals to be too complicated, not user-oriented, and inaccurate or incomplete (GAO Report, 9/1979, pp. 5, 6). Technicians spend excessive time searching for information in manuals and oftentimes end up removing nondefective parts. On the basis of a 1974 study examining current paper-based technical data, the Air Force, for example, found:

> . . . that it could avoid costs of about $108 million annually by improving manuals so that maintenance personnel would spend less time searching for information and removing aircraft parts that are not defective (GAO Report, 9/1979, p. 6).

These deficiencies have been found by GAO to result in substantial costs to all military services. Text-graphic combinations for conveying technical data were also found in some instances to be improperly organized. These results have caused relevant personnel to "lose confidence in the manuals, maintenance performance to suffer, and equipment readiness rates to go down" (GAO Report, 7/1979, p. 8).

The GAO Report also revealed that the military services reliance upon technical manuals for communicating information is projected to increase throughout the 1980s. In 1977, the Air Force Logistics Command, for example, estimated that "an additional 5 million pages would be produced during the next 5 years. That increase in pages alone would cost about $1.5 billion" (GAO Report, 9/1979, p. 9). The Command also told Air Force Headquarters that this cost increase, together with DOD budget reductions, created "an urgent need for a new, advanced technical order system which would be more cost effective.'

The report issued by GAO underscores the fact that all military services, including the Navy, are experiencing similar difficulties with technical manuals and aptly sums up the general problem with the following statement:

> Maintenance manuals frequently are not easy to use and are not current or accurate. These deficiencies prevent maintenance personnel from doing the most efficient job and could affect the safety of equipment, systems, and personnel. The problems have existed for many years and are increasing because the complexities of new weapons systems have caused substantial increases in the data needed for maintenance. The increase in the size of the manuals has caused a corresponding increase in the cost of issuing and revising them. If DOD could update its manuals in a more timely manner, improve their accuracy, and make them easier to understand, it could improve maintenance and substantially reduce costs (GAO Report, 9/1979, p. 9).

Difficulty in reading and understanding technical materials is certainly not limited to the armed services. Office personnel everywhere struggle with directions for operating new word processors and data processors. These problems are magnified especially for inexperienced workers who have other job responsibilities as well as company executives who may feel threatened by being required to change the way they approach information-processing tasks.

Text/Graphics

An examination of a variety of instructional materials of a technical nature reveals that, regardless of the specific content, information is invariably presented through a combination of text and graphics. Given the widespread use of this format, it would seem that theories of learning or models of information processing would have included a consideration of this form of communication. Furthermore, it would seem likely that clear-cut guidelines for the effective design of technical documentation would have long ago been established. Reviews of relevant literature, however, revealed that this is certainly not the case--

decisions concerning design formats for the production of procedural texts, it was found, may depend more on the whims of the technical writer and on illustration and production variables than on empirical research (see Wright, 1977; Hartley and Burnhill, 1977; Stone, 1977, 1978, 1979; Stone and Glock, 1981; Crandell, 1979, 1980).

Should the instructional designer include graphics as adjuncts to the text? And if so, which type of graphic--an exploded view of the entire facia of the equipment or segmented pictures displaying parts of the equipment at fixed points? Does the ability to follow directions for equipment operation or maintenance depend on the cognitive predisposition of the user? Apparently, few experimenters examining instructional materials of a technical nature have asked such questions.

One reason, perhaps, for the lack of a concentrated research effort to assess the effects of graphic/text combinations on the user's comprehension is the pervasive attitude among both reading researchers and practitioners that procedural texts were not really meant to be read. Traditionally, technical materials have rarely been studied for their communication value. Stone (1978) contends, furthermore, that the results of research (albeit sparse) in this area are, for the most part, seriously flawed in that the reading materials used are never identified or adequately described. Thus, it is difficult, if not impossible, to determine the compatability of the graphics and texts.

Even when technical manuals or texts are well designed, many users lack efficient strategies for processing such material (see Wright, 1977; Crandell, 1979). Consequently, we need to know much more than we do about both the design of the instructional materials and the ways in which people access, process, and use the text and graphics in technical materials, particularly in procedural texts.

Because of the crucial role that procedural materials play in training programs, maintenance of systems, and operation of assorted equipment, information regarding their ability to convey instructions in an efficient and accurate manner is needed. Past research has failed to generate any consistent guidelines for helping technical writers/illustrators to plan and design effective formats for presenting technical information. Consequently, organizations, including the military and industry, have no clear-cut facts for the effective design and utilization of instructional materials using text-graphic combinations. The results have often been costly and time consuming for all personnel who rely on those manuals. Therefore, to the extent that relevant personnel are trained by or rely upon technical materials for job performance and training, information regarding the effectiveness of the materials design should be ascertained.

The Reader/User

In addition to the media format design, another practical area of research regarding technical materials is reader characteristics. Investigators have paid little attention to the aptitude or attitude of the reader (user) toward the instructional materials (Waller, 1977; Wright, 1977). In a review of the research literature on typography and design, Wright (1977) found that most of the studies tended to assume that differences in ability between users were of no major consequence when it came to selecting procedures for presenting technical information. A similar conclusion was reached by Waller (1977): researchers, authors, and publishers have tended to ignore the fact that procedural texts were meant to be read. Research, he maintained, has focused on typography and production variables and has paid little attention to the individual differences of the reader. He concluded that reader characteristics may be partly responsible for many of the inconsistent findings reported in the research literature and continues:

> In order to proceed in a more consistent fashion, those of us in the business of researching instructional design would do well to consider the reader as an individual and the variables influencing him/her as an active processor of information (Waller, 1977).

If we are to understand and facilitate comprehension of technical materials, we need not only tools for analyzing and describing information present in such materials but also the effects of fixed and changeable characteristics of the user.

Cognitive Style

One prerequisite of an ideal system for communicating procedural instructions is that the condition of the directions (the content and format of presentation) match well the characteristics of the user--abilities, interests, prior knowledge, and learning style. It is unlikely, however, that any system of instructional design could fully embody this ideal. Most decisions for designing procedural materials to date stem from less salient variables such as designer intuition, experience, and production costs. To this extent, they have become somewhat standardized and tend to ignore individual user characteristics. Although this approach may appear to have the distinct advantage of being economically prudent, it may be less effective than instructions designed with certain users or groups of users in mind.

A construct developed by psychologists to interpret the antecedent conditions of individual differences and one which may be useful to those in the business of designing instructional materials is cognitive style. Cognitive styles have been defined as individual ways in which people remember, think, and problem solve (Messick, 1976). They represent consistencies in the form rather than the content of cognition. Cognitive styles are considered to be distinctive modes of apprehending, storing, transforming, and using information. As such, their influence extends to a variety of human activities that implicate cognition, including reading (see Witkin, 1975; Simon and Rosenberg, 1977; Cohn, 1968; Watson, 1969; King, 1972; Fine and Kobrick, 1980).

The literature on cognitive style has been growing rapidly, and there are several measures available to assess the increasing number of style and control mechanisms identified. Comprehensive reviews of the literature on individual differences and cognitive style may be found in Banta (1970), Gardner et al., (1959), and Wallach and Kogan (1965). Without attempting to discuss all of the varied dimensions of cognitive style, it is useful to consider that there have been two divergent theoretical positions around which investigators have tended to group themselves (Wallach and Kogan, 1965). On the one hand, there are those researchers who hold that cognitive styles are habits of processing information. An example of a processing model is the dimension of cognitive style referred to as reflectivity-impulsivity. It is the position of the advocates of the reflective-impulsive strategy that differences in rate of information processing are relevant to how an individual problem solves. Impulsive individuals have a fast conceptual tempo and report the first classification sequence that occurs to them. Reflectives, on the other hand, will delay classifying information and consider all available alternatives.

Gardner and Jackson (1960) are representative of the second position posited by researchers to explain cognitive styles. They view cognitive styles more as ego control mechanisms that regulate the flow of information between internal need states and environmental demands on the individual. Thus, it makes a difference whether one considers individual variations in human behavior as the result of modes of functioning (information processing) or ego control mechanisms (internal need states). In the former case, instructional design strategies would be based upon the reader's mode(s) of processing. In the latter, efforts would tend to focus on the innate capacities of the reader. This research embraces the information-processing paradigm as the preferred way of viewing cognitive styles. In considering the effect of cognitive style on instructional design, it may be more cost-effective to evaluate how different instructional formats impact different users' information-processing strengths or weaknesses than to try to consider all of the psychological variables influencing users as they attend to the procedural directions.

The potential of cognitive style as a research tool in human learning led to a consideration of using this construct as a means of investigating the information-processing activities that underlie reading behavior. Cognitive styles, by embracing both perceptual and intellectual domains, provide an effective framework for evaluating the interactive effects of text and graphics on reader (user) characteristics.

Indeed, if we accept the view of the user as an active participant in the communication process, we are challenged to investigate whether individuals' cognitive styles influence their ability to comprehend procedural directions. Do graphics interact with certain individuals to enhance or interfere with their understanding of the directions? Does the cognitive style preference of certain groups of military recruits predispose them to one type of information format over others? It is suggested in this research study that in order to effectively plan and design procedural texts which maximize the user's comprehension of the task, researchers should recognize and focus on the user's strengths and weaknesses for processing technical information.

Educational Cognitive Style

Cognitive style has been introduced and reintroduced into the psychological literature over a period of at least 50 years. Messick (1976) has described the various uses of cognitive style such as Witkin's field dependence-independence. The term cognitive style has even been found in the business management literature (see McKenney, 1974). Joseph E. Hill has developed a model of cognitive style which he called Educational Cognitive Style (ECS). He suggested that it can be used for analyzing the type of behaviors an individual employs when confronted with an instructional task. Hill's cognitive style model, however, is different from the above models in that it was developed to be used primarily in an instructional context. To this extent, Hill's model of cognitive style seems appropriate for examining the variables which influence the reader's comprehension of procedural instruction.

Cognitive style, as conceptualized by Hill, deals with a total information-processing model: the ability to decode symbols (input), the ability to manipulate symbols and the concepts they represent (processing), and the ability to recode experience into symbols for transmission (output) (Hill, 1970). The mode of behavior individuals employ when searching for meaning is defined by Hill as their Educational Cognitive Style (ECS). Hill, unlike some of the earlier psychological researchers, believed that the Educational Cognitive Style of an individual can be changed by the process of education and that the model can be applied to most educational tasks.

The individual's Educational Cognitive Style is reflected by a number of elements representing the learner's mode of behavior. These elements or modes of behavior are displayed in the form of an Educational Cognitive Style Map, which is a Cartesian product of four sets. The measurement of an individual's Educational Cognitive Style can be accomplished through the administration of a battery of tests (Heun, Heun, and Schnucker, 1976; Nunney, 1972). The results of the tests are analyzed by a computer software program and displayed on a printout which graphically presents the data in the following sets:

the symbolic orientation set, the cultural determinant set, the modality of inference set, and the memory set.

Although Hill identified the elements of the memory set, he indicated that "the state of the art of using electrophysiological measurements and biochemical factors as mappings of memory is not sufficiently developed to allow their use in the classroom at the present time" (Hill, 1976). Since the body of information relating to the memory set is inconclusive, the Cartesian product, or the Educational Cognitive Style Map representing the individual's Educational Cognitive Style, is currently limited to the first three sets.

Information in the first set pertains to how individuals derive meaning from information through the utilization of symbols (Hill, 1970). Two types of symbols are indicated: theoretical, which are comprised of words and numbers, and qualitative, which employ sensory data. The ability to utilize these symbols, he suggested, is an essential part of the learning process. This capability as it applies to learning situations may be considered in terms of how the general utilization of these symbols affects their meanings and how the individual tends to employ them in the process of learning instructional tasks.

The second set of an Educational Cognitive Style Map focuses upon those behaviors an individual employs when coming to a decision. It is based on the premise that the ability to understand and use symbols is often dependent on the social context in which they are applied. This aspect of one's Educational Cognitive Style is a quantification of the extent to which an individual is influenced by social environment.

While the data in the first two sets deal primarily with the preferred modes of input of information, the cognitive style elements included in the third set convey information about how the individual makes an inference or mediates the symbolic information. In particular, Hill maintains there are consistencies in the manner in which individuals tend to reason through the symbolic information; and once this is established, it can be used to facilitate learning. The four modalities identified in this set of data include the following: a magnitude inferential pattern, where individuals tend to categorize and segment information as they draw conclusions; a difference inferential pattern, where one-to-one comparisons of concepts are noted; a relationship inferential pattern, where the individual uses the ability to synthesize a number of dimensions into a unified or composite meaning; and an appraisal modality, where the individual uses all of the above modalities, giving equal weight to each one in the reasoning process.

Data from the three sets provide information about the information-processing skills of the individual. They also may provide indices of ability to use verbal and pictorial stimuli in the reading and learning situation. Hill suggested that interpretations of an individual's Cognitive Style Map can be made by combining data from different sets of the map to consider the interaction effect on learning tasks. In some settings, certain elements can be more crucial than others.

Once an Educational Cognitive Style Map has been developed or produced, it may be possible to utilize the information to design procedural texts that will incorporate the information-processing strengths and weaknesses of the user.

For example, if the individual or group prefers to process the directions by means of linguistic symbols alone, then the procedural directions could be presented in a text-alone format. If, on the other hand, a training group prefers to learn the information through visual symbols, then the presentation format can include pictures and other graphic information. Graphic-text amalgams may be the optimal format for certain groups of users who tend to process information fastest by using text and graphics together.

Although the Educational Cognitive Style of an individual is a relative concept and is dependent upon one's educational level and cultural background, it may provide a means of analyzing, interpreting, and evaluating instructional situations where decisions concerning the design of procedural materials are important.

Statement of the Problem

The design of procedural texts, as pointed out in the first section of this paper, tends to be geared to the average reader. To this extent, media design decisions have not considered the information-processing strengths of the reader. They have limited each reader or user of the materials to the same instructional conditions. The purpose of the study was to determine whether a measurable learned characteristic--Educational Cognitive Style--can be used to predict differential reading efficiency and comprehension as a function of the media format design. An experiment was conducted to test empirically the above question.

Methodology

The subjects were selected for the study based on the results of a battery of cognitive style tests (Hill, 1970) administered to them during the fall of 1978. The tests were computer scored and the results stored on disc. The results took the form of an Educational Cognitive Style Map, a term which Hill used to describe the individual's cognitive style preferences for mediating symbolic information.

Hill (1970) suggested that by combining elements from the different sets of data on the map, it was possible to construct cognitive style maps useful for examining the match between the learner's strengths for processing information and an educational task.

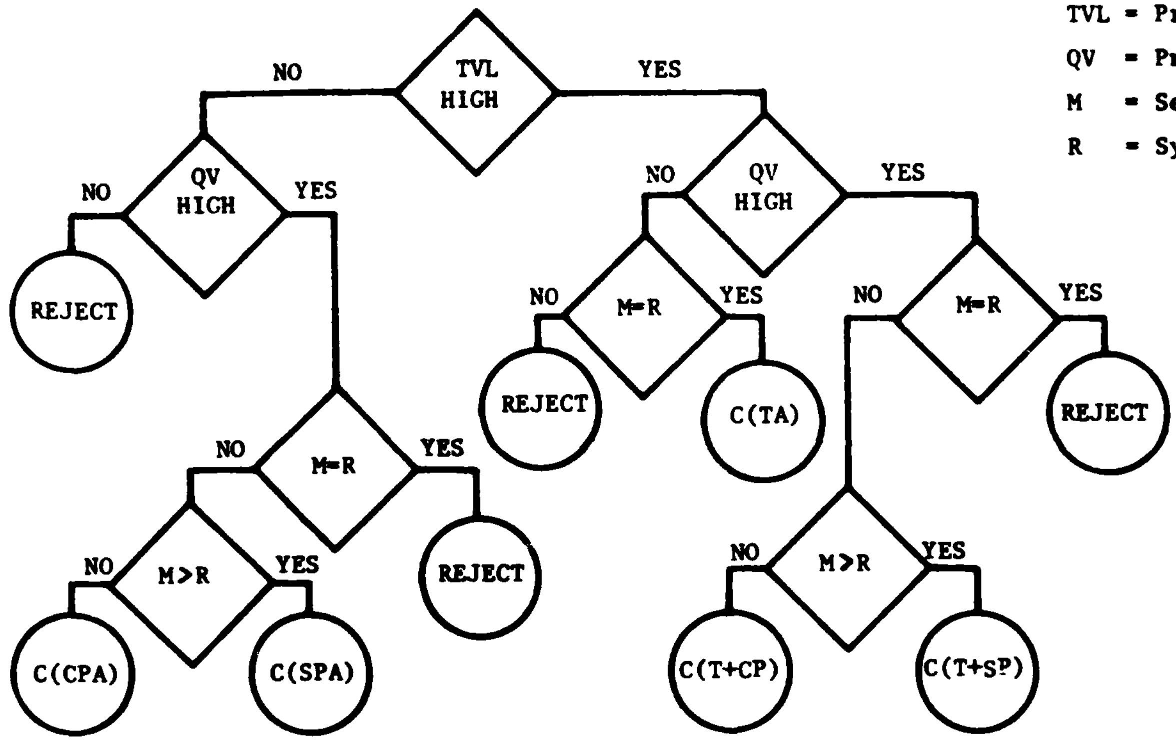
This research study focused on those combinations of cognitive style elements found on an ECS map which may be used to determine a subject's strengths for processing and understanding procedural instructions. Five ECS types were identified and selected for this study: subjects who indicated a preference for instructions in words alone C(TA); subjects who indicated a preference for instructions in words and segmented pictures C(T+SP); subjects who preferred instructions in words and a composite picture C(C+CP); subjects who preferred instructions in a composite picture alone C(CPA).

Figure 1 presents a flow chart developed to help select the ECS subjects for this experiment.

Instructional Materials

Five different media formats for presenting performance-task directions were designed to match the ECS preferences of the subjects noted above; these included a text-alone format (TA), a text-plus-segmented-pictures format (T+SP), a text-plus-composite-picture format (T+CP), a segmented-pictures-alone format (SPA), and a composite-picture-alone format (CPA). Table 1 shows the procedure used to identify the five media formats which make up the treatment conditions for this experiment.

TVL = Prefers Words
QV = Prefers Pictures
M = Segments Information
R = Synthesizes Information



C(TA) = Prefers Text Alone
C(T+SP) = Prefers Text + Segmented Pictures
C(T+CP) = Prefers Text + Composite Picture
C(SPA) = Prefers Segmented Pictures Alone
C(CPA) = Prefers Composite Picture Alone

Figure 1. Flowchart for Identification and Selection of Cognitive Style Types

Table 1. Procedure for Identifying Media Format Conditions.

INSTRUCTIONS	MEDIA FORMAT: TA	T+SP	T+CP	SPA	CPA
Text	yes	yes	yes	no	no
Segmented Pictures	no	yes	no	yes	no
Composite Picture	no	no	yes	no	yes

The directions for the task are found in Appendix A, which contains the text directions; Appendix B, which contains the segmented pictures; and Appendix C, which shows the composite-picture.

Subjects

The subjects for this study consisted of 46 males and 40 females ranging in age from 18 to 38 years old. The entire sample was drawn from first- and second-year students from 12 different curriculums at a community college in upstate New York. All students were volunteers who agreed to participate in an experiment in reading which would be conducted at the college.

Equipment and Layout of the Research Laboratory

The task selected for this experiment was an assembly task found in the Fishertechnik 100 Model Kit. The kit is of German manufacture and contains a variety of plastic and metal parts which can be attached to each other in a large number of ways. The particular model selected involved the use of eleven (11) different kinds of parts and resulted in the assembly of a loading cart, or what is sometimes called a handcart.

Subjects were seated at a table, facing a partition in a section of a science and math learning lab at the college. A drawing of the physical layout of the subject's work area in the research laboratory is displayed in Appendix D of this paper. A Singer Caramate projector was located just to the left and another just to the right in front of the subject. A digital clock was situated to the right and just behind the subject so that it was outside the subject's visual field. A SONY uni-directional microphone was attached to the upright holding the digital clock. Additional equipment used in the experiment included: 25 hours of Memorex UCA-60 videocassette tapes, a SONY U-Matic Model VO-1600 videocassette deck, 2 SONY VCK-3210 televison cameras, and a SONY Switcher/Fader SEG-1 special effects generator.

One television camera was positioned next to the caramate projector and to the left and was directed at the subject's hands and workspace just in front of the subject. The other camera was in front of the subject and was directed at the subject's head. Only the model parts, caramate projectors, and one camera were visible to the subject. All other apparatus was placed behind a partition.

The Experiment

Subjects were seated at a work table and instructed how to operate the caramate projectors. Introductory information as to the nature of the experiment, familiarization with the task components, and instructions for the assembly task were given during this time. Once the subject was ready to perform the task, he or she was presented with procedural instructions in one of the five treatment conditions (media format). These instructional formats were present on either one or both caramate projectors, depending on the treatment condition.

Videotape recordings were made using the special effects generator. Each camera produced a different view of the subject. One camera, directed at the subject's hands, provided information as to the progress of the task along with the recording of the time on the digital clock. A second camera directed at the subject's head provided information as to whether the subject was looking at a slide of text, illustration, or at his or her hands. This camera also made it clear when a subject changed a slide. This enabled us to tell which slide(s) were on the screen(s) at a given time.

The special effects generator produced a split image on the monitor and on the videotapes so that the experimenter could obtain precise information as to task efficiency (duration and frequency of looking at text, slide, and hands) and task performance (number of errors). The videotape recordings were subsequently viewed and scored for time and error data by the experimenter. By this procedure, a second-by-second analysis of each subject's reading efficiency and task performance was documented.

Results and Conclusions

It was hypothesized that the subjects' performance on the task would vary to the extent that they were presented with media formats which matched their Educational Cognitive Style. To test this hypothesis, an experiment was conducted. Eighty-six (86) male and female subjects from a community college were randomly assigned to one cell within a 5 X 5 factorial design. The results of analysis of variance of subjects' performance (time and error scores) indicated a trend in the direction of the hypothesis; although no statistically significant interactions were found between subjects' cognitive style preference and media format design, main effects for both cognitive style type $F(4,61) = 4.645$ $p < .003$ and media format $F(4,61) = 3.549$ $p < .001$, were indicated. Figure 2 presents a graphic display of the pooled reading times for all subjects.

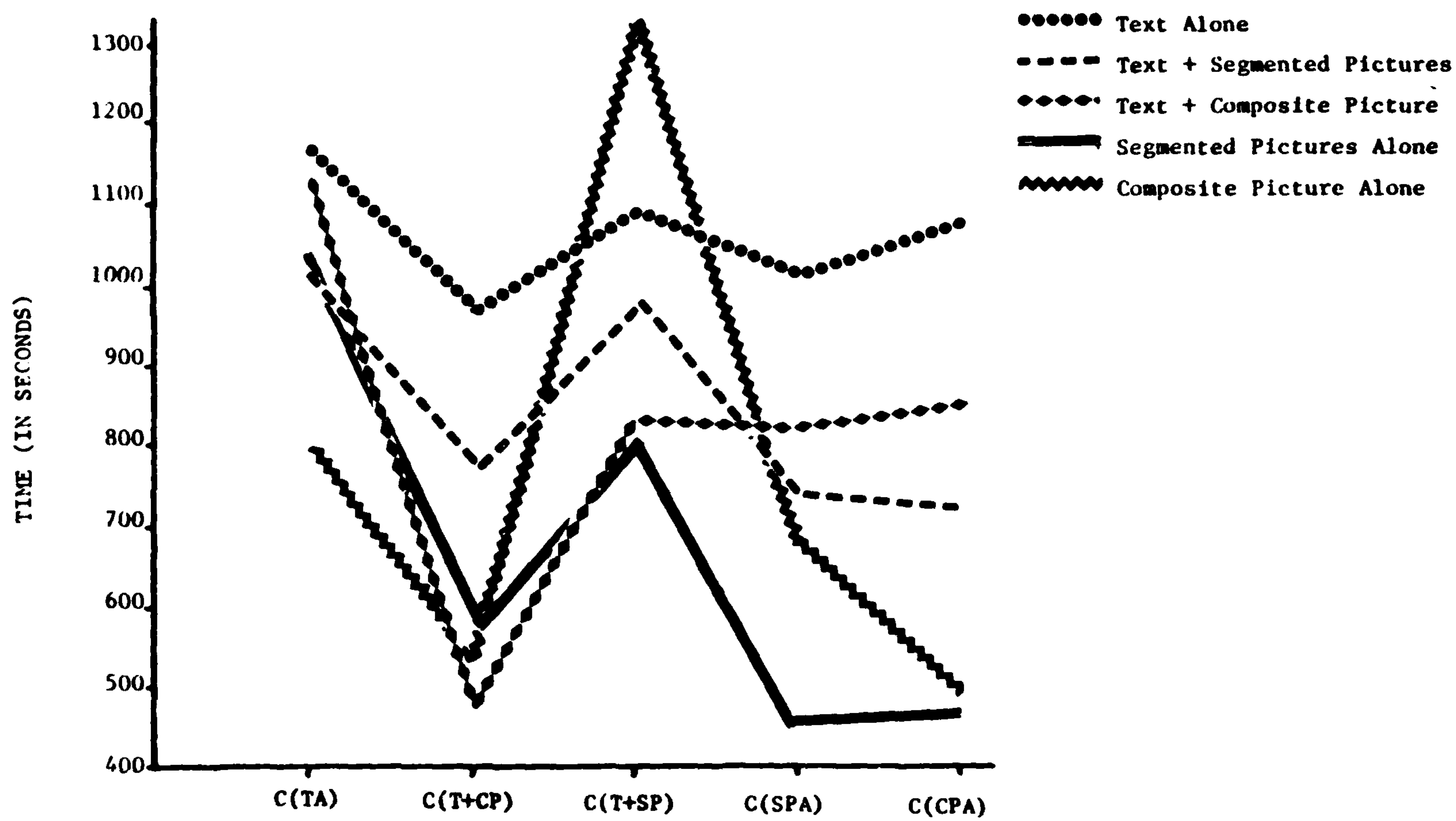


Figure 2. Mean Total Reading Time for Cognitive Style Type and Media Format

From Figure 2 it can be seen that the mean times for the text-alone group were significantly higher than for the segmented-pictures-alone group. This graph also shows that segmented pictures alone, regardless of cognitive style type, tend to be the most efficient format for all subjects, while text alone is the most time-consuming format for presenting the assembly task information.

Effect of Cognitive Style on User Efficiency

As indicated above, a main effect of cognitive style type $F(4,61) = 4.645$, $p < .003$ on total mean reading time was found, and a subsequent one-way analysis was performed to compare the difference in means for all cognitive style types. The results of this ANOVA indicated that a significant difference existed between groups $F(4,85) = 5.096$, $p < .001$. Post hoc analyses revealed that subjects who preferred text-plus-composite-picture C(T+CP) completed the assembly task significantly faster than subjects who preferred text alone. Table 2 presents the mean reading times and standard deviations for all cognitive style types in the analysis.

Effect of Cognitive Style on User Accuracy

User accuracy on assembly was highest for subjects who preferred to process the instructional symbols by means of a graphic(s)-alone format. They made fewer errors and were generally more accurate on this task than cognitive style types who preferred to have the instructions presented in a text-alone or text-plus-picture(s) format. Table 3 presents a summary of the mean number of errors during the performance task for each treatment condition.

Overall accuracy results indicated that this procedural task seemed best suited for individuals who prefer to process technical instructions by means of a graphic display independent of text.

Table 2. Mean Total Times for Completion of Performance Task by Cognitive Style Type and Media Format (in seconds)

MEDIA FORMAT

COGNITIVE STYLE TYPE	(TA)	(T+SP)	(T+CP)	(SPA)	(CPA)	TOTAL
C(TA)	M 1150 S.D. 401	M 1009 S.D. 286	M 1134 S.D. 610	M 1030 S.D. 297	M 797 S.D. 366	1024
C(T+CP)	M 960 S.D. 251	M 773 S.D. 129	M 474 S.D. 193	M 586 S.D. 356	M 532 S.D. 119	665
C(T+SP)	M 1076 S.D. 200	M 969 S.D. 396	M 826 S.D. 378	M 805 S.D. 418	M 1307 S.D. 768	997
C(SPA)	M 1008 S.D. 237	M 743 S.D. 176	M 806 S.D. 175	M 448 S.D. 59	M 673 S.D. 194	731
C(CPA)	M 1059 S.D. 403	M 704 S.D. 91	M 836 S.D. 200	M 462 S.D. 107	M 494 S.D. 174	711
TOTAL	1050	838	817	657	721	

Table 3. Mean Error Score (on a scale of 1-5) for Performance Task by Cognitive Style Type and Media Format

MEDIA FORMAT

COGNITIVE STYLE TYPE	(TA)	(T+SP)	(T+CP)	(SPA)	(CPA)	TOTAL
C(TA)	M 1.40 S.D. 1.05	M 0.29 S.D. 0.51	M 0.18 S.D. 0.23	M 1.92 S.D. 1.67	M 0.00 S.D. 0.00	0.87
C(T+CP)	M 1.77 S.D. 0.96	M 0.24 S.D. 0.24	M 0.00 S.D. 0.00	M 0.46 S.D. 0.59	M 1.00 S.D. 1.81	0.73
C(T+SP)	M 2.16 S.D. 0.68	M 0.70 S.D. 0.67	M 0.03 S.D. 0.06	M 1.00 S.D. 0.90	M 0.44 S.D. 0.77	0.95
C(SPA)	M 1.81 S.D. 0.39	M 0.27 S.D. 0.26	M 0.00 S.D. 0.00	M 0.00 S.D. 0.00	M 0.00 S.D. 0.00	0.41
C(CPA)	M 2.11 S.D. 1.54	M 0.05 S.D. 0.07	M 0.52 S.D. 1.05	M 0.00 S.D. 0.00	M 0.27 S.D. 0.55	0.60
	1.81	0.32	0.17	0.65	0.41	

Effect of Media Format on User Efficiency

The ANOVA on mean total reading times showed a main effect of media format $F(4,61) = 3.549$, $p < .01$. Scheffe's test was then used to compare the mean reading times under the five treatment conditions: (TA), (T+SP), (T+CP), (SPA), and (CPA). This post hoc analysis indicated that subjects, on the average, spent less total time completing the performance task when instructions were presented in a segmented-picture-alone (SPA) format. Post hoc comparisons also confirmed that subjects in the text-alone (TA) condition took significantly more time to complete the performance task than subjects in the segmented-pictures-alone group.

Table 4 below clearly shows that subjects in the text-alone condition (TA) took by far the greatest amount of time to complete the assembly of the model. Overall, these results clearly indicated that text alone (TA) is an inefficient instructional format for presenting procedural instructions for this task, while segmented pictures alone appear to be the most efficient media format for presenting the instructions. The mean times in Table 4 also indicated the extent to which pictures facilitated the speed with which subjects decoded the procedural instructions. Whenever text was added to pictures, it served to distract subjects from the pictures, and this resulted in an increase in the mean total time required to complete the task.

Table 4. Mean Total Time (in seconds) and Standard Deviation for Each Media Format

	Treatment Condition								
	Segmented Pictures			Composite Picture			Text Alone		
Text	T+SP	M	838	T+CP	M	817	TA	M	1050
		S.D.	239		S.D.	360		S.D.	288
No Text	SPA	M	657	CPA	M	721			
		S.D	337		S.D.	428			

<u>Effect of Media Format on User Accuracy</u>

Reading comprehension has been represented earlier in this paper as a measure of accuracy of assembly for completion of the performance task in this experiment. The two-way ANOVA on user errors showed that there was a significant main effect of media format on error rate, $F(4,61)) = 10.954$, $p < .001$. This indicated that the type of design format presented to the user groups differentially affected their comprehension of the directions. A subsequent one-way analysis to elucidate the differences between treatment conditions was performed, which indicated a significant difference between groups, $F(4,85) = 7.987$, $p < .001$. Multiple comparisons of the mean number of errors indicated that subjects in the text-alone condition made significantly more errors compared with all other treatment groups (T+SP, T+CP, SPA, and CPA).

The analysis also revealed that the subject's accuracy on this task improved when graphics were present. This result was consistent for all graphic conditions regardless of the presence or absence of text. Table 5 below shows the mean error scores from this analysis along with the mean total times subjects took to complete the assembly task for each treatment condition. From this table it can be seen that text alone (TA) was clearly the least efficient and most error prone condition.

Table 5. Mean Error Score (on a scale of 1-5) and Mean Total Time for Each Media Format

	Media Format				
Variable	TA	T+SP	T+CP	SPA	CPA
Time (in seconds)					
M	1050	838	817	675	721
Error					
M	1.81	.32	.17	.65	.41

Data in Table 5 do not reveal the percentage of subjects in the five treatment conditions who made no errors or corrected their errors by the end of the assembly of the model. Such information, however, is perhaps of even greater strategic value to the overall investigation of how media design affects user comprehension. Certain assembly tasks (as is the case in some Naval projects) need to be presented in media formats where the error range is kept as low as possible.

Information concerning the percentage of subjects in each condition who made no errors by the end of the assembly task is presented in Table 6 below. These results indicated that the composite picture conditions (T+CP, CPA) provided the optimal format(s) for accurately conveying the technical instructions for the assembly of the model.

Table 6. Percentage of Subjects Following the Specified Sequence of Assembly for the Performance Task (No Errors)

	Segmented Pictures		Composite Picture		Text Alone	
Text	T+SP	25	T+CP	62	TA	0
No Text	SPA	47	CPA	66	N/A	

Effect of Text on Error Correction

The data presented in Table 7 below indicate that the addition of text to graphics resulted in a higher percentage of subjects who corrected their errors by the end of the assembly task. Three times as many subjects corrected their errors in the text-plus-segmented-pictures condition compared with the segmented-pictures-alone condition. About twice as many corrected their errors in the composite-picture-plus-text condition compared with the composite-picture-alone condition.

Table 7. Percentage of Subjects in Each Condition Who Corrected Their Errors by the End of the Performance Task

	Segmented Pictures		Composite Picture		Text Alone	
Text	T+SP	38	T+CP	13	TA	0
No Text	SPA	12	CPA	6		

Text apparently acts as a troubleshooting aid to graphics in that it provided a medium for identifying and correcting errors for this task; while graphics, on the other hand, tended to present error-free information in that more subjects made no errors when presented with graphics alone for instructions. This result held true regardless of the type of graphic used.

Figure 3 shows a summary of the data presented in Tables 6 and 7. Also indicated in Figure 3 is the percentage of subjects who made errors but did not correct their errors by the end of the performance task.

Conclusions and Implications for Future Research

This experiment examined the possible interactions between Educational Cognitive Style (ECS) and media format design on understanding procedural directions. Five ECS types were identified and selected for the study. Five different media formats for presenting performance task directions were designed to match the ECS preferences of the subjects noted above.

It was hypothesized that the subjects' performance on the task would vary to the extent that they were presented with media formats which matched their ECS preference. Findings of the research, however, were negative: and the hypothesis was not upheld. While some trends in the direction of the hypotheses were noted, no statistically significant interactions between ECS type and media format were found. However, obtained significant differences among media formats and ECS types were found, and discussion regarding the implications of these findings for designing technical instructions is appropriate.

Graphics or Text

Graphics were found to have a strong facilitative effect on task efficiency and a small, though significant, effect on task performance. These results tend

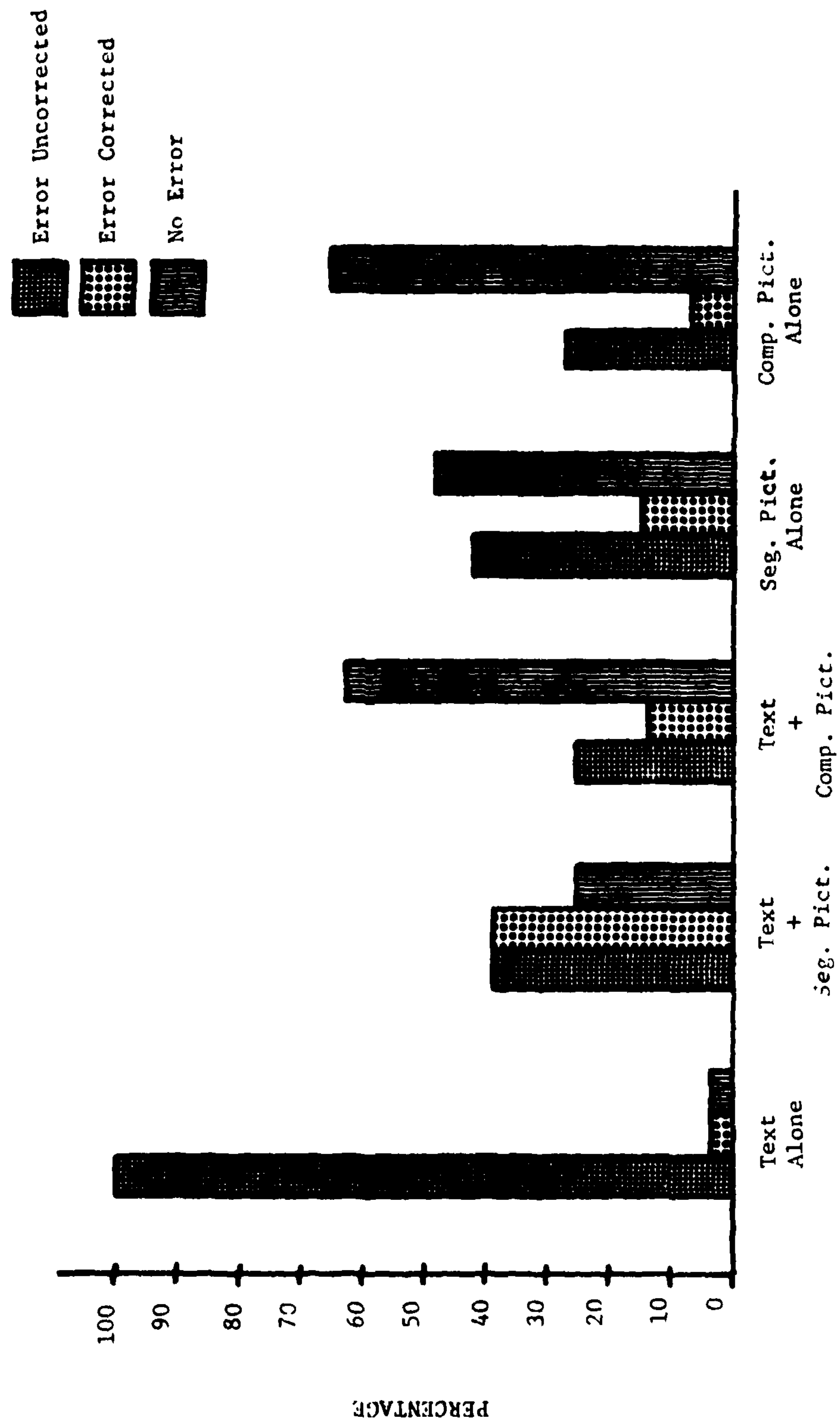


Figure 3. Comparison of Error Scores on the Performance Task (in PCT)

to favor graphic formats when the directions to be followed are of a procedural nature. This finding does not agree with other researchers who have found that pictures have a debilitating effect on reading comprehension (see Dwyer, 1970; Vernon, 1953; and Samuels, 1970). Unlike Samuels' findings, for example, text alone was clearly the least efficient and most error-prone format for presenting the directions for this performance task. These findings suggest that some form of information which enabled subjects to complete more quickly and accurately the assembly of the model was available in the graphics and not in the text. The highest percentage of subjects, for example, were able to complete the assembly of the model with no errors when the information was presented to them in the form of a composite-graphic format. The addition of the text to the composite graphic only slightly reduced the degree of accuracy for subjects; whereas, when text was added to segmented graphics, subjects increased their errors by almost 50 percent.

What information was in the composite graphic that facilitated the reader's understanding of the directions? Since the composite graphic did not confine the subjects to encoding information in any particular sequence, it may be that subjects who made the smallest number of errors on the task were those whose cognitive style revealed that they processed information by synthesizing and relating the symbolic information found in the medium. They were, it appears, cognitively matched to the design format of the composite graphic display.

One way to explain this is through the concept of supplantation. Salomon and Snow (1970) defined supplantation as a function which occurs when the media presentation replaces the covert operation which the learner would have to activate on his or her own. Did the composite graphic supplant the operations necessary for effective mediation of the directions? Two observations may help to shed light on this question. First, the ECS type who tended to do best on this task was one who processed information by associating and relating it. The composite graphic, by virtue of its exploded design format, in effect, mirrors the mental operations used by the superior cognitive style type. Second, other ECS types made fewer errors when presented with the composite-graphic format. Perhaps the depiction of the entire model enabled other cognitive style types to supplant the mental operations which occurred spontaneously for the superior group. The relationship between parts of the model and stages of the task was clearly more readily available to all subjects in the composite-graphic conditions.

The finding that graphics alone resulted in more accurate performance than graphics and text ran contrary to Denburg's (1977) finding that the more information provided to readers, the more likely they will find and integrate information for a correct response. If this were true, subjects would have had their best performance when text and graphic(s) were presented together; but as seen earlier, accuracy on task was highest when graphics were presented independent of text. One exception to this was noted: although the addition of text to graphics resulted in more errors, it also resulted in more subjects correcting their errors by the end of the assembly of the model. Text enabled subjects to troubleshoot their errors when it was used as an adjunct to graphics. What information enabled people to locate and correct errors when graphics and text were presented together? Perhaps this question, as with the case of the composite graphic result, may be better answered in future research where more precise monitoring of subjects' eye movements during reading is available.

Critics of pictures as reading aids have generally assumed that whenever a picture is present, individuals will bypass the text and concentrate on the picture. Examination of the amount of time subjects spent looking at the text and at the graphic(s) in the conditions where the two were presented together indicated that this was not the case: subjects, on the average, spent more time looking at the text than the graphic(s). The finding that subjects also made more errors when text was presented with graphics makes the above assumption more suspect.

User Characteristics and Media Design

One important observation which arises as a result of these findings is that general principles of design for procedural texts may need to include a model of the processing strategies required for effective understanding of the directions. As indicated earlier, subjects who preferred to process information by means of a text and composite graphic tended to make fewer errors than the other ECS types used in this research. This result may have implications for producers of technical materials. Certain ECS types, it seems, are more cognitively compatible with the operations necessary for efficient and accurate processing of procedural directions.

Can reading behaviors be isolated and taught to individuals who may rely on processing strengths less conducive to reading procedural materials? The success of an attempt to develop modes of cognition in the individual will depend, to a large extent, on the degree to which cognitive styles are malleable. The possibility entertained here is that through manipulation of educational experience, we might convert ECS processing elements into cognitive strategies or what may be termed "coping strategies." If possible, this would enable the individual to have a conscious choice among alternative modes of processing procedural information. Hill's dimension of cognitive style makes this idea possible, for unlike many other theories of cognitive style, his concept of ECS includes a systematic plan for changing the style preferences of the individual.

Other researchers have presented similar themes. Salomon (1972), for example, found that specific modes of communication which characterize different media may affect the minds of those who are exposed to them. He concluded that some "isomorphism between the external system and an internal, representational one is implied" (Salomon, 1972).

Provided that such a system of teaching cognitive coping strategies for reading instructional materials could be devised, how would it be operationalized? One reliable technique which may be employed to develop more optimal processing of procedural materials is found in that body of research described as "mathemagenic" behavior. This term was originally coined by Ernst Rothkopf (1970) to signify the learner activities which lead to successful performance. Perhaps mathemagenics could be used to design advanced textual organizers to be encoded into the directions and presented to the reader as part of the procedural instructions. In this way, the mathemagenic strategy, together with the posing of particular coping strategies, may combine to produce an influence on understanding the directions that may not have occurred had either technique been used separately.

When it is known that the procedural directions are to be used by a certain training group that may have difficulty reading and understanding technical materials, the above strategies could be used to help alleviate the problem. For example, Naval instructional packages used for training purposes could be analyzed to determine if they are compatible with the information-processing behaviors of cognitive style types who are most adept at reading and understanding the technical materials. If the materials are not found to be compatible with the processing strengths of the superior cognitive style type, then one of two strategies could be employed. Either the materials could be redesigned around the mathemagenics principles noted earlier, or the group itself could be trained to employ a more accurate and efficient approach to using the directions.

Although the diagnostic procedure here is usually illustrated in terms of matching the cognitive style of two individuals (i.e., learner and teacher) it can be used equally effectively to match the style of a training group with a mode of understanding required by a given set of technical instructions. The assumption made here is that a more effective processing of the directions will take place if the requirements made of the user tend to make greater demands upon his or her strengths for processing technical information and minimize the demands upon his or her weaknesses. In this way the directions take on more psychological meaningfulness for the user and reduce much of the cognitive dissonance between the user and the task itself. This results in a form of job enrichment where one of the primary motivators for the training group is the user-oriented directions or what might be referred to as "directions for directions" (Hackman and Oldham, 1976; Ausburn and Ausburn, 1978).

Since users cannot always count on designers to offer up information in a variety of media formats, they should be equipped to transform the information to a form that renders it maximally effective. The development of cognitive coping strategies based on the habits of people who tend to be compatible with processing procedural texts appears worthy of attention to those in the business of designing instructional materials.

Media Design and Production Costs

It is true that illustrated instructional texts cost more to produce than nonillustrated ones. However, the findings of this study indicate that the extra cost may be worthwhile. If the directions are to convey efficient and error-free information, then they must be designed so they are based on educational criteria in addition to production considerations. Failure to convey accurate information may prove more costly in the end as was demonstrated in the GAO findings regarding the DOD's paper-based technical data system.

However, the question still remains, what constitutes an optimal media format? The results from this experiment indicate there are three possibilities:

1. User efficiency (indicated by time on task) tended to be greatest when the information was presented in segmented graphics alone.

2. User comprehension (indicated by accuracy on task) was highest when the information was presented in a composite graphic alone.

3. User correction of errors was greatest when the directions were presented in text accompanied by a composite graphic.

A fourth possibility is to combine the first three formats into what can be described as an optimal design order. That is, when efficiency, accuracy, and the ability to troubleshoot one's mistakes are needed, then the optimal media format may be a graphics-text amalgam. For a procedural task, this would consist of a composite graphic on the task, followed by segmented graphics, followed by a composite graphic accompanied by a text.

The small computer market is one area where printed instructional materials are becoming increasingly important. As competition in the small computer and word processing markets increases and training costs soar, more and more organizations, military and civilian alike, are substituting packaged instructional materials for classroom training. Efforts to design these materials for inexperienced/novice workers so that they can be easily understood have not been very successful. This problem is compounded further by the fact that these same employees are often threatened by the change in their job requirements and the high expectations for quick productivity by their managers.

The techniques for analyzing instructional materials and training groups described in this paper are one way in which computer manufacturers can more systematically develop training programs and materials which are geared to the user but still cost-effective.

The importance of art work, then, in procedural texts tends to make graphics essential to the design of effective instructional materials. However, graphics based on established principles of information-processing behaviors will prove more beneficial to the user than one which focuses on production criteria alone.

Although the results and generalizations presented in this study are considered tentative, they are in general agreement--there seems to be a consistent finding that points logically to one kind of media design for all users of procedural texts--a composite graphic when the subject matter is of a procedural nature. Educational Cognitive Style was not found to interact with media design, but one ECS type tended to be superior on this task--those whose ECS indicated a preference for the composite graphic. However, only through additional research using more precise monitoring of reader's eye movements will we be able to tell more exactly what type of information the composite graphic conveyed to cause these results.

No claim of finality is made here for the conclusions that have been drawn, only that they present a reasonable and empirically based set of information for the design of procedural materials. However, it must be pointed out that the performance measure used in this experiment was a relatively simple one. Additional research needs to be done to see if these findings can be replicated using a second and more complicated task. Further studies using other quantifiable indices of structuring reading behaviors and of cognitive style models are currently being investigated in our laboratory.

Summative Statement

The experiment described in this paper and the methodology employed to examine graphic-text combinations for their communication value indicate that design style for technical materials need no longer be based on arbitrary and unaccessible conventions--empirical guidelines, although still incomplete, are evolving. Information describing the kind of language people can best understand while reading directions is now available.

Although the experimental procedure used in this investigation cannot solve all of the problems organizations may be experiencing with the use of technical information, it may help to increase performance by military and industrial personnel, especially where time and errors are important to the outcome of training and maintenance procedures. Further, knowledge about the information-processing demands of training tasks and job skills, along with a better understanding of media design formats, can be used to determine what types of technical manuals and job training aids are essential for high job performance.

APPENDIX A

TEXT DIRECTIONS FOR THE EXPERIMENT

To form handle one: Insert a short rod through a clip so that the clip is near the end of the rod.

To form handle two: Insert another short rod through another clip so that the clip is near the end of the rod.

To form column one: Assemble one small block and three large blocks end to end.

To form column two: Assemble another small block and three other larger blocks end to end. (Each column should begin with a small block connected to three larger blocks.)

Attach an angle block to the end groove of the large block for column one. (The angle block has two tabs; one tab is inserted into the end groove of the large block; the other tab on the angle block should be facing you.)

Repeat the same procedure for column two.

To form a wheel assembly: Insert the long rod through the open groove in the two angle blocks. The two long columns should now be parallel to each other and approximately the width of two large blocks apart.

Next, place a washer over one end of the long rod so that it is flush with the angle block. Place a screw hub over the same end of the long rod so that its threads point away from the angle block. Next, place a tire over the same end of the rod. Next, place a nut hub over the same end of the long rod with its threads toward the screw hub.

Screw the nut hub and screw hub together with the tire between them. Finally, place a washer over the same end of the long rod so that it is flush with the nut hub.

Repeat this procedure to form the other wheel assembly on the other end of the long rod. (When the wheel assembly is complete, the long rod should only extend approximately 1/4 inch beyond the outside washer.)

To form the base: Insert a flat piece into a side groove of a large block. Take another large block and attach it to the other end of the flat piece. (Make sure that the ends of the flat piece are flush with the ends of the large blocks. The tabs on the ends of the large blocks should point in the same direction.)

Next, connect two large blocks end to end to form a short column.

Attach the two large blocks containing the flat piece to the small column by inserting the tabs on the ends of the large blocks into a side groove of the short column.

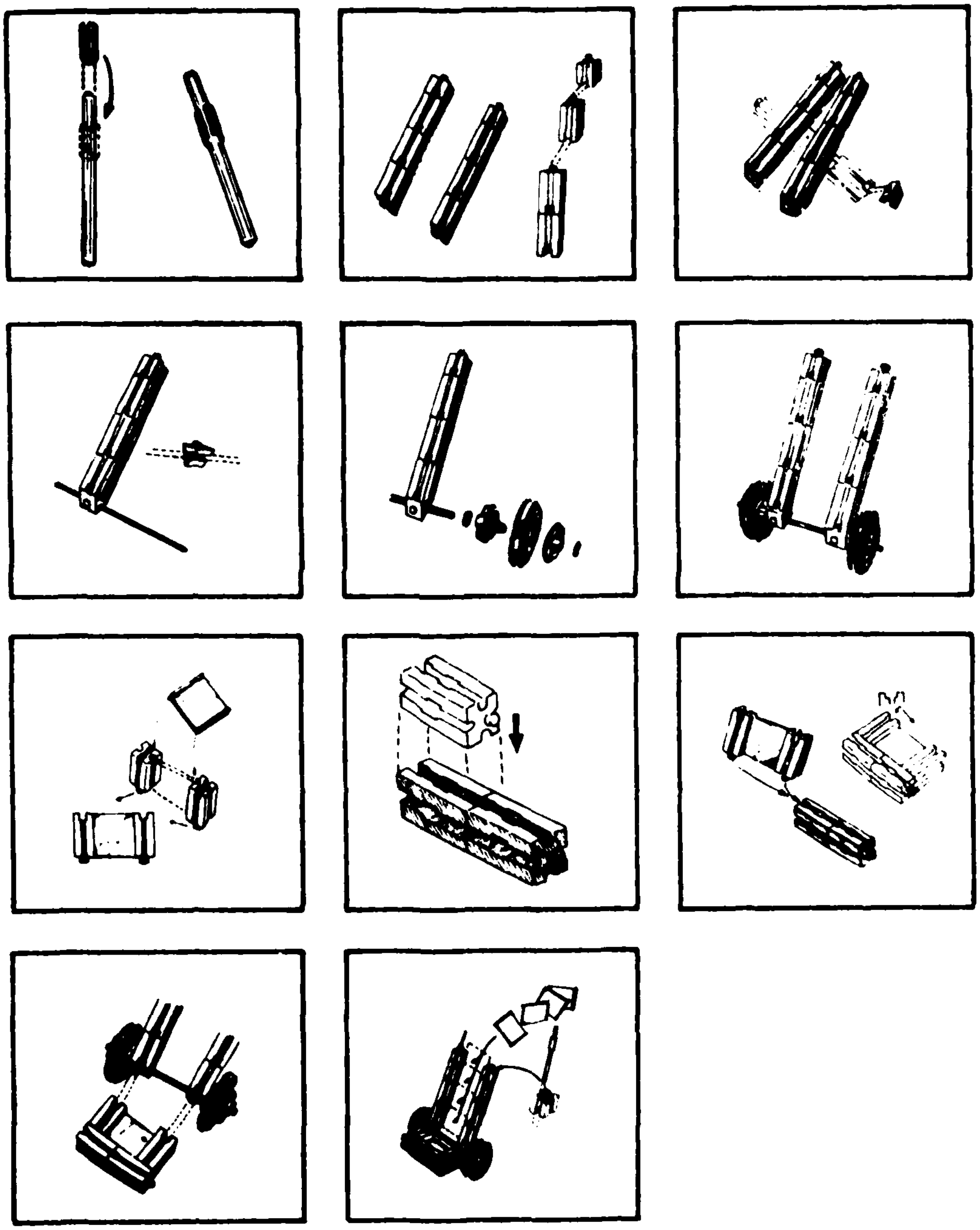
To attach the base to the axle assembly: Notice that the base has two large blocks which are connected to a small column. Connect the open groove at the end of each of these large blocks to the exposed tabs of the axle assembly. Be sure that the flat piece in the base has its smooth side up.

To form the back: Insert four flat pieces between the two long columns. Slide each flat piece into place using the side grooves in the blocks. (All the flat pieces should have their smooth sides on the same side.) The flat pieces should be pushed down the grooves of the columns until the first flat piece is flush with the base.

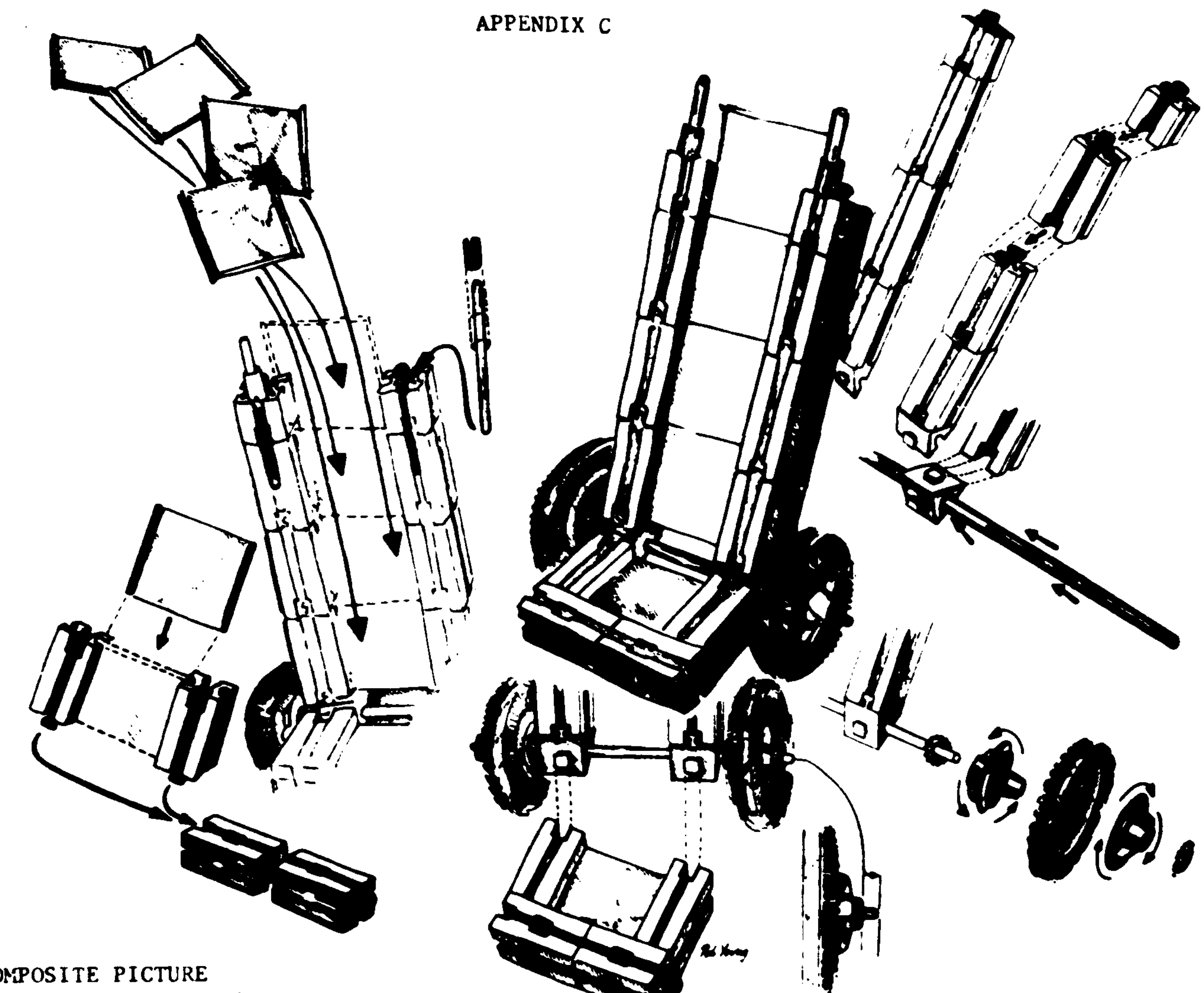
Next, the handles should be inserted in the end of the back with exposed tabs. Each handle should be inserted in the grooves at the front of the back so that the clips are resting against the ends of the blocks. The openings on one side of each clip should fit over the tabs at the ends of the columns. This completes the assembly of the loading cart.

APPENDIX B

SLIDES OF SEGMENTED PICTURES
(Not Shown in accurate scale)



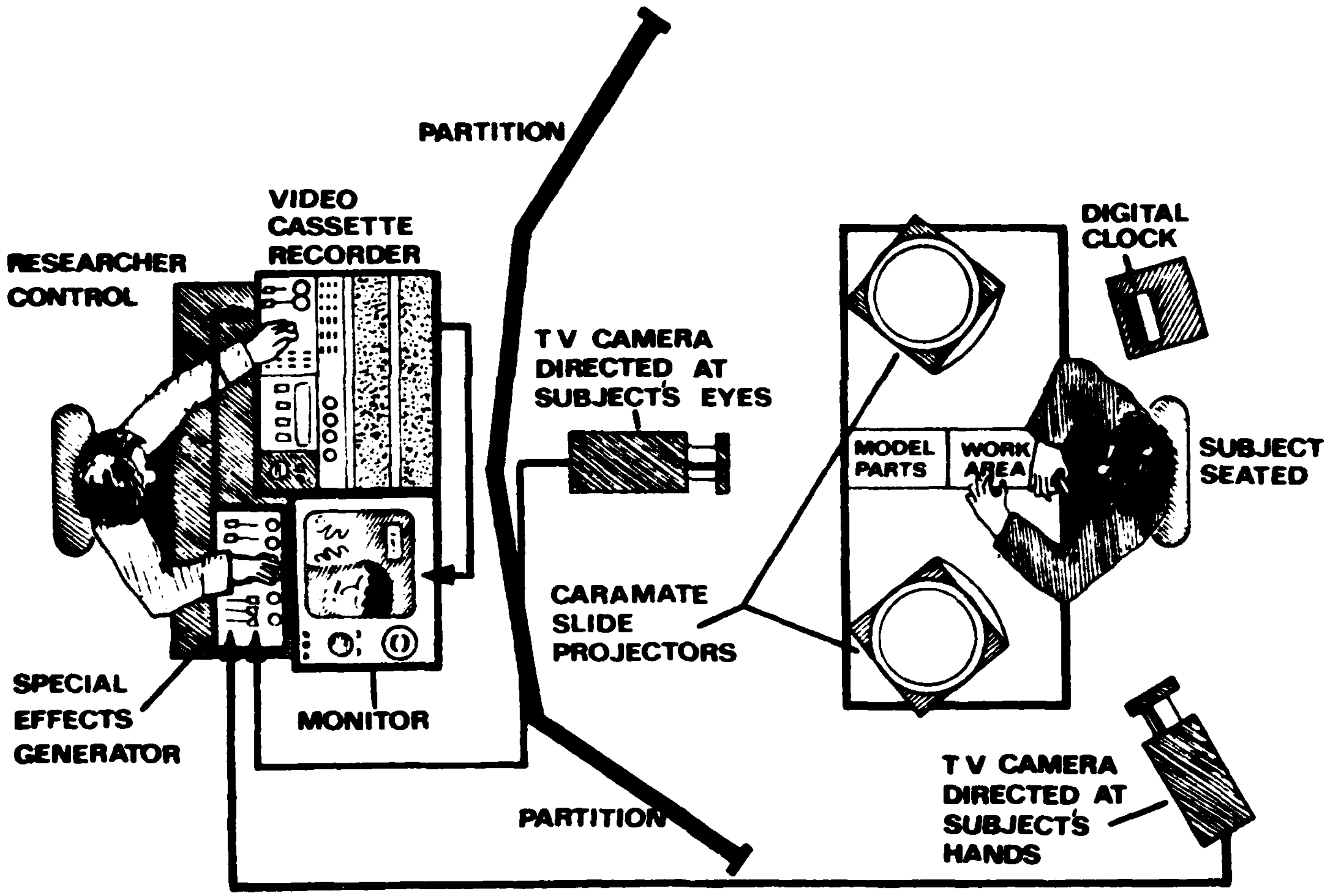
APPENDIX C



SLIDE OF COMPOSITE PICTURE
(Not shown in accurate scale)

APPENDIX D

LAYOUT OF THE RESEARCH LABORATORY



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